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JULY 29, 1985

CHEMICAL & ENGINEERING

NEWS

FINAL PROGRAM
ACS meeting in Chicago
Page 33

Industrial Gases

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CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 63, Number 30
CENEAR 63 (30) 1–136
ISSN 0009-2347

JULY 29, 1985

News of the Week

■ **Academic science research facilities are in a sorry state; how to fund modernization was subject of NAS meeting.** **Page 4**

■ **U.S. chemical company earnings in second quarter continue decline from year-earlier level.** **Page 5**

■ **National Transportation Safety Board calls for federal regulations regarding hazardous materials in railroad yards.** **Page 6**

■ **Chemical weapons production will get the go-ahead if conference committee deletes from authorization bill requirement that NATO allies must agree to deploy them.** **Page 6**

■ **Coalition of Indian professionals in U.S. hopes to raise $3 million for a clinic and research center for Bhopal victims.** **Page 6**

Government

The federal government would be required to notify both past and present workers exposed to chemicals that might cause chronic diseases under Pennsylvania Congressman's bill. **Page 15**

Science

Students, senior scientists discuss ethical and social dimensions of scientific decision making at Student Pugwash conference. **Page 18**

Education

All members of U.S. team win medals in International Chemistry Olympiad held in Bratislava, Czechoslovakia. **Page 23**

Industrial Associates Program at Purdue engages both academic and industry scientists in projects for mutual benefit. **Page 24**

Books

"Normal Accidents" by Charles Perrow examines certain high-risk technologies with an eye toward abandoning nuclear power. **Page 30**

Final Program

Program includes complete listing of the scientific papers to be presented at the ACS annual meeting in Chicago. **Page 33**

Cover: Union Carbide's Linde division air separation plant at Niagara Falls, N.Y.

Letters 2
Editor's Page 3

Concentrates
Business 8
Government 14
Science/Technology 17

The Departments
People 124
Newscripts 136

Business

Fortunes of industrial gases are not all the same: Nitrogen demand is high, but call for oxygen and hydrogen is at a standstill and carbon dioxide is affected by lack of low-cost feedstock. **Page 9**

Industrial Gases: Producers Face Mixed Demands

Demand for nitrogen surges, but that for oxygen and hydrogen has stalled; supply of carbon dioxide is hurt by inadequate low-cost feedstock

Bruce F. Greek, C&EN Houston

Producers of the various industrial gases are coping with several different demand pressures. For some gases, such as nitrogen and argon (a small-volume but important gas), demand is strong, and producers are running their plants for optimum production. For certain other gases, such as oxygen and hydrogen, demand has become lackluster. And for carbon dioxide, the problem of inadequate low-cost feedstock holds down the amount that producers can sell.

For those gases whose demand is increasing, producers not unexpectedly are adding to capacity and raising prices. However, price increases, most of which were effective May 1, have been modest, probably just covering the increased costs of electricity, a major expense in operating air separation plants used to produce oxygen, nitrogen, and argon. Programs to reduce costs also have been put in place, spurred by the declines in demand during the past recession, which led to low plant operating rates and to the closing of considerable capacity. These cost-reduction programs have tended to help profitability when price increases covered just a part of increased costs.

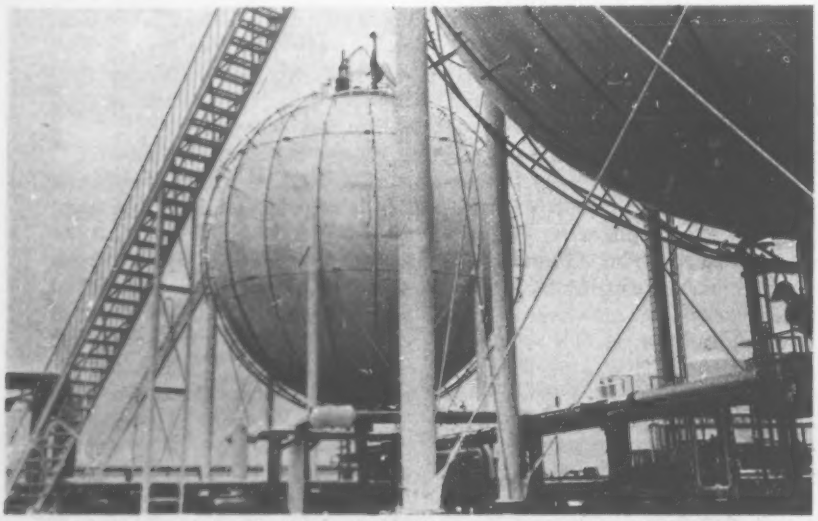
Key Chemicals

Some of the shut-down capacity has remained closed since the recession, and some additional capacity has since been shuttered, especially captive capacity located adjacent to steel mills. Because these capacity shutdowns involved relatively large units, the present capacity to produce industrial gases remains below prerecession levels in spite of capacity expansions in the past year. Few new air-separation plants are under construction to supply the merchant part of the industry, even with the increase in plant operating rates, because returns haven't yet risen to levels needed to cover the investments—except in special areas such as supplying the electronics industry.

Merchant volumes of these gases will continue to rise at modest rates—in the range of 4 to 8% annually, on the average—for the rest of the 1980s. Additional plants will be built during this time to satisfy growth in regional demand. But few, if any, shut-down plants of any size will be moved to new locations, because such plants are less energy-efficient than are new plants and because it is costly to move them. Unfortunately, the old plants will not be scrapped very rapidly, and as a result, the apparent capacity will remain excessive and operating rates will remain understated for the industry.

Prices received by producers for the gases will continue to rise slowly. In addition to the competition among gas producers, the possibility that customers might build their own gas-producing plants will continue to hold down prices. In addition, the increasingly higher quality of gases required for the electronics industry and other specialized uses will have to be paid for by consumers. The higher prices that result from supplying higher-quality gases will justify new capacity through the 1980s.

For details of the near-term outlook for the major-volume industrial gases, please see the following pages.



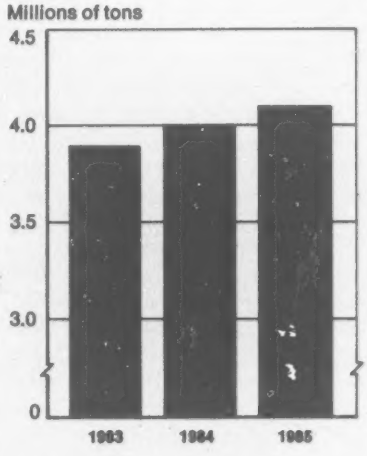
Air Products & Chemicals' liquid hydrogen storage tanks in New Orleans

CO_2

Carbon dioxide

- ***Demand steady***
- ***Supply tight***
- ***Prices holding***

PRODUCTION (nonoilfield)



MAJOR PRODUCERS

Air Products & Chemicals, Airco Industrial Gases, Chemetron Corp., Liquid Carbonic, UGI Corp.

HOW MADE

Recovered as coproduct in ammonia production and in manufacture of ethanol by fermentation, obtained from refinery and chemical operations and from natural wells

MAJOR USES (nonoilfield)

Refrigeration 40%, beverage carbonation 20%, enhanced oil recovery 10%, chemical manufacture 10%, metals fabrication 10%

FOREIGN TRADE

Exports—negligible, imports—1 to 2% of demand

PRICE

About $65 per ton

Merchant sales and production of carbon dioxide in 1985 are expected to grow about 5%, subject to availability of carbon dioxide sources. This growth would bring reported production to 4.1 million tons, or possibly a little more, up from slightly less than 4 million tons reported as preliminary estimates for 1984.

Whatever the reported production of carbon dioxide actually totals in 1985, it certainly will be far less than all production of this industrial gas. By far the largest quantity of carbon dioxide produced industrially comes from natural gas wells. Most of it is pipelined to oil fields where it is used to increase oil production through the enhanced oil recovery (EOR) technology of carbon dioxide flooding of underground formations containing petroleum.

Merchant production of carbon dioxide continues to be limited by available sources of raw material. About three fourths of merchant carbon dioxide is recovered as a coproduct in the manufacture of ammonia. Merchant carbon dioxide so obtained doesn't account for all of the carbon dioxide coproduced in making ammonia, because large quantities are consumed, usually on site, to make urea, a fertilizer and an ingredient for making polymeric resins such as the urea-formaldehyde adhesives. Currently, the other major source of carbon dioxide for the merchant market is the coproduct of grain fermentation to make ethanol, most of which is now used as an octane enhancer for gasoline.

Both major sources of carbon dioxide depend on the operation of ammonia and ethanol plants for their primary product. In turn, demand for the primary product depends on fertilizer demand and on tax incentives to make alcohol-gasoline mixtures (gasohol) nearly competitive with unleaded gasoline prices. The minor sources for merchant carbon dioxide from refineries and chemical plants are rather steady sources, but are small as is the recovery from wells. Availability of feedstock to carbon dioxide plants varies with operation of the source plant.

Capacity to make or recover carbon dioxide seems relatively large in relation to reported production, although no actual capacity estimates are available. Several recovery units have been or are being built adjacent to ethanol plants. These new plants are scheduled to go on stream in 1985 or early 1986. If feedstock is available to operate the newer capacity and to operate existing capacity about as in the past, then production for all of 1985 might be higher than 4.1 million tons. However, feedstock limitations have always prevented full operation of the recovery plants for long term.

As a result of the supply limitations, consumption of carbon dioxide is held down. The largest use, for refrigeration, runs into competition from nitrogen. It's debatable which of these two industrial gases is the more suitable for food freezing; no real resolution of this question has been reached, but each gas (consumed in liquid form) has developed its own niche. The continual growth in sale of "fast foods" helps this use of carbon dioxide and accounts for much of the growth in the merchant sales.

Beverage carbonation accounts for the second largest use of carbon dioxide. Growth in this use likely will be less than average for all merchant carbon dioxide, but it remains a good market with relative stability.

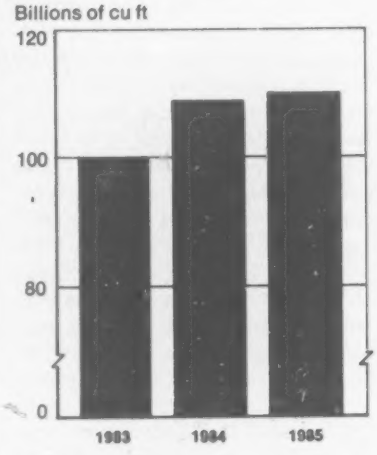
Various industrial uses of carbon dioxide, such as chemical manufacture and metals fabrication, take about 20% of the merchant supply, if the EOR use is excluded. For chemical operations, the largest use is in blanketing. Merchant carbon dioxide used in EOR is less than 10% of the total and is used largely on a spot basis for testing the suitability of a carbon dioxide flood to augment oil production. Future prices of crude oil are important in this use.

H_2

Hydrogen

- ***Demand level***
- ***Government use down***
- ***Prices steady***

PRODUCTION



MAJOR PRODUCERS

Air Products & Chemicals, Airco (BOC Group), Liquid Air, Union Carbide's Linde division

HOW MADE

Reforming of natural gas, recovered as coproduct in production of chemicals, and various small-volume methods

MAJOR END USES

Fats and oils hydrogenation 20%, government (space and weather programs) 20%, electronics manufacture 20%, chemical production 10%, metals treating and processing 10%, petroleum refining 10%

FOREIGN TRADE

Negligible

PRICE

About $1.25 per 100 cu ft

Merchant hydrogen production and sales in 1985 will about match the 109 billion cu ft produced in 1984. The lack of growth in hydrogen's merchant market stems from shifts in major areas of consumption. Demand is dropping for government uses—especially the space program—metals processing, and chemical manufacturing. Other markets may post gains, however, offsetting some of the declines.

Merchant sales of hydrogen account for 10% or less of total hydrogen production. Far bigger than all merchant sales are such captive uses as making ammonia or methanol and in the various hydrotreating processes involved in petroleum refining. These uses are almost completely supplied by on-site hydrogen production. Because of this captive production, no estimates of the volume of hydrogen involved have been made. Guesses are based on the amount of ammonia and methanol produced each year plus assumptions on the amount of hydrogen required for refinery uses, from which must be subtracted the amount of hydrogen generated in refineries by cracking and reforming processes.

For nonpetroleum refining uses, most hydrogen, probably about 80%, is made by reforming natural gas (methane) using oxygen from the air. Much of the remainder is obtained as a coproduct from the manufacture of chlorine and caustic soda by electrolyzing sodium chloride brine. Because of the large demand for hydrogen in refining, a large part of this hydrogen also is made by reforming natural gas. This "on purpose" production is in addition to the hydrogen traditionally recovered from cracking and reforming.

The consumption pattern for hydrogen is as unclear as its production pattern. Much overlap between captive and merchant hydrogen output occurs. Users of merchant hydrogen always have looming over them the decision whether to buy or to make. Often, hydrogen users make part of their needs, and buy the rest.

The dynamics of overlapping supplies can be illustrated by hydrogen use in refineries. Refiners often buy part of their hydrogen needs until their needs become so large that the addition of another gas reforming unit can be justified. As a result, sales to refiners have been one of the fastest-growing areas for merchant hydrogen producers.

Other markets for hydrogen fit into a few general groups. Hydrogenation of edible fats and oils is estimated to account for about 20% of merchant sales of hydrogen. And practically all of the hydrogen used in the government's space program is purchased. The space program requirements have slipped recently because major work in developing current rocket engines has been completed and because space missions have only begun to increase.

Electronic component manufacture has been and continues to be a fast-growing use of hydrogen. Almost all of this hydrogen comes from merchant producers who commercially provide 99.9999% purity routinely because of the low boiling point of hydrogen. Any higher purity may require a shift to on-site further purification.

Chemical manufacturing (excluding ammonia and methanol) and metals processing are supplied hydrogen by both merchant and captive production, but the hydrogen source of each situation differs. For example, one hydrochloric acid manufacturer might use coproduct hydrogen from chlorine cells, in an entirely captive use of the hydrogen. Cyclohexane producers also may use captive hydrogen, but because most producers are chemical subsidiaries of oil companies, the hydrogen may come from the parent company's refineries. With these many chemical uses growing and declining, this hydrogen market is currently a no-growth area for hydrogen.

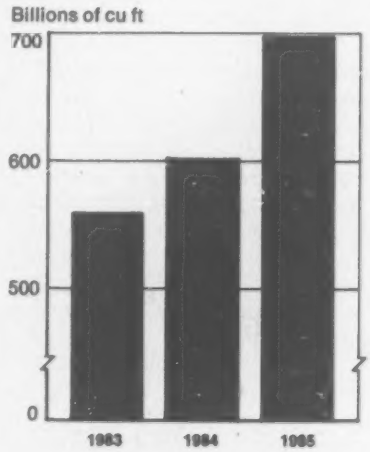
So use of merchant hydrogen in electronics production and by refiners will grow this year and next. But other uses will decline, balancing the growth.

N_2

Nitrogen

- **Demand up well**
- **Most uses growing**
- **Prices firming**

PRODUCTION



MAJOR PRODUCERS

Air Products & Chemicals, Airco (BOC Group), Big Three Industries, Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air, pressure swing adsorption using various adsorbents

MAJOR END USES

Blanketing atmosphere for chemical processing 25%, enhanced oil recovery 25%, electronics manufacturing 15%, metals treating and processing 15%, aerospace 5%, freezing meat, poultry, and seafood 5%

FOREIGN TRADE

Negligible

PRICE

50 cents per 100 cu ft

Gain in nitrogen demand contrasts sharply with that for oxygen. Production of nitrogen this year likely will exceed 700 billion cu ft, up about 17% from 1984. This follows a notable but smaller gain of about 8% in 1984.

A large part of this increasing use of nitrogen results from enhanced oil recovery (EOR). During 1984, much of the additional air separation capacity built (some of which did not start up until 1985) was dedicated to EOR use. However, no additional plants for EOR now are under construction, companies say, so the spate of recent capacity gains will be over for at least a year.

Even with growth in most other major uses of nitrogen, the EOR market has been growing so fast that it has become the largest use of nitrogen, according to industry sources. In 1985, EOR will take close to 30% of all nitrogen produced, nosing out chemical manufacturing, where nitrogen is used mainly to provide a blanketing atmosphere.

If crude oil prices decline as expected, EOR use of nitrogen still will hold up well, because EOR seldom involves much additional high-cost drilling of wells. The justification for EOR use of nitrogen depends largely on the costs associated with building the air separation plant, operating the plant, and injecting the nitrogen into the oil well.

Nitrogen competes with carbon dioxide for use in EOR, with carbon dioxide still believed to be much more widely used. Physical properties, particularly the critical pressure of carbon dioxide, can have a major influence on the choice of which gas may be used as an EOR aid in any given field. If pressure, and to some degree, temperature, are not overriding limits to its use, carbon dioxide has advantages over nitrogen. Some of these are low cost and miscibility with crude oil, which lowers crude oil's viscosity to allow better flow through formations.

Uses of nitrogen in chemical production continue to expand, but not at the rates at which they once did. Most of the continuing increase can be attributed to the shift toward making more specialty chemicals, whose synthesis more likely requires an inert blanketing atmosphere than does that of commodity chemicals.

As usual, electronics manufacturing gets major attention from merchant suppliers of nitrogen. The quality requirements have become very high—with 99.9999% nitrogen the standard for the majority of sales—and higher purities are not unusual any more. This kind of quality costs a lot to obtain and maintain, so selling prices of this small segment of merchant nitrogen sales, possibly 3% of the total, are well above those of volume sales. The pressure to obtain even-higher-quality, inert-gas shielding will increase as semiconductor chips become more complex.

Electronics manufacturers so far have been willing to pay for the quality and service in order to get the required nitrogen. Their future needs are keeping suppliers working to improve quality at a cost that likely will keep the profitability of this small part of the business well ahead of the rest.

Other uses of nitrogen have less spectacular outlooks, but they also keep adding to total demand. Metals treating and processing and aerospace uses somehow remain close to holding their market shares, even as some individual uses decline. Freezing of meats, poultry, and seafood has been growing steadily with the growth of fast-food outlets. This highly visible consumer area is becoming saturated, and the number of new outlets added each year is declining. However, efforts to increase volume at existing outlets likely will tend to keep demand for these frozen food products growing—and thus for nitrogen as well.

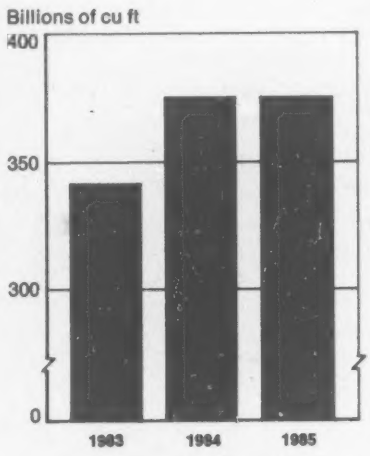
With all significant uses of nitrogen growing substantially this year, it probably will be a banner year for this industrial gas.

O_2

Oxygen

- **Demand on hold**
- **Merchant sales up**
- **Prices up slightly**

PRODUCTION



MAJOR PRODUCERS

Air Products & Chemicals, Airco (BOC Group), Big Three Industries, Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air, pressure swing adsorption using various adsorbents

MAJOR END USES

Primary metals manufacturing 55%, chemicals manufacturing 20%, partial oxidation processes 10%, metals fabrication 5%

FOREIGN TRADE

Negligible

PRICES

54 cents per 100 cu ft

For the near term, growth in oxygen production has stalled. Production this year probably will roughly equal that of 1984, about 375 billion cu ft, with the possibility of a slight gain to about 380 billion cu ft. This slowdown follows a 9% annual gain last year.

The problem that oxygen producers face this year involves oxygen's largest use: that of making steel either in basic oxygen furnaces or in electric furnaces. Steel production for all of 1985 will be lackluster at best because of changes in steel demand and sources of supply. An important additional factor in the steel-demand situation will be the careful control of inventories of finished steel, lest the inventories get out of hand as they did at about this time last year.

Basic oxygen furnaces are the largest part of the steel industry's use of oxygen, with most of it supplied by adjacent air separation plants and delivered at relatively low purity by pipeline. Electric furnaces usually produce specialty steels in smaller tonnages and use oxygen supplied mostly by merchant oxygen producers who deliver the oxygen as a liquid and also supply on-site equipment for regasification and handling.

Steel producers using either kind of furnace are facing little or no growth in demand for 1985. Their woes stem from slowdowns in two major markets: the U.S. auto industry and the construction industry. Moreover, imported steel accounts for a growing part of consumption in these two areas as well as in many others.

Because of their locations, specialization, and adaptibility, electric furnace steel producers are seeing somewhat better times than are the large producers who generally use basic oxygen furnaces. This situation means better sales for merchant suppliers of oxygen than for those suppliers who operate captive plants.

Merchant oxygen accounts for an estimated 20 to 25% of reported oxygen production, and demand for it likely will grow 5% in 1985. The major uses include chemicals and electronics manufacture, metal fabrication, medical consumption, and many smaller uses. Chemicals manufacture, excluding such uses as partial oxidation processes, also has a substantial share of its oxygen needs supplied by captive air separation plants. Because chemical production will grow at a relatively slow rate in 1985, this use of oxygen also will be up just marginally.

Oxygen supplied for partial oxidation processes also comes largely from merchant producers, although some large consumers have captive sources. Much of this consumption goes to make hydrogen for various subsequent hydrogenation processes. Partial oxidation is expected to continue to grow as an outlet for merchant oxygen. However, the decision whether to make or to buy hangs over each merchant oxygen user.

As with other industrial gases, electronics manufacture is showing one of the better gains in oxygen consumption. Most of this oxygen is supplied by merchant producers. As yet, the total volume remains relatively small, but the requirements in some cases for high purity and the expected growth make this use of high interest to oxygen suppliers.

Many other smaller-volume uses of oxygen are almost entirely supplied by merchant producers. The fortunes of these uses vary with time, technological developments, and outside influences. For example, efforts to reduce costs of medical services as yet have not had a noticeable effect on oxygen demand in medical uses.

Until steel loses its dominance in oxygen consumption, production of oxygen will rise and fall with steel operations. When a steel mill is closed, almost always the adjacent air-separation plant also closes. With no significant additions to steel capacity in view, even in small electric furnaces, oxygen demand will remain on hold for the rest of 1985 and well into 1986.